23 p. T → NASA's QUALITY PROGRAM

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INTRODUCTION - THE CHALLENGE

I am very pleased to have this opportunity to tell you of NASA's Quality Program. I know that many of you are already involved with important NASA work. Others will become involved as our space programs continue to gain breadth and vigor in meeting the national challenge of space leadership. This challenge was again expressed by President Kennedy upon completion of his September tour of key NASA space facilities. Speaking at Rice University on September 13, 1962, President Kennedy said:

"This generation does not intend to founder in the backwash of the coming age of space. We mean to be a part of it--we mean to lead it.

For the eyes of the world now look into space--to the moon and to planets beyond--and we have vowed that we shall not see it governed by a hostile flag of conquest, but by a banner of freedom and peace.

We have vowed that we shall not see space filled with weapons of mass destruction, but with instruments of knowledge and understanding. Yet the vows of this Nation can only be fulfilled if we in this Nation are first, and therefore we intend to be first."

I have a short motion picture clip which will give you a condensed and very miniaturized picture of the space we are just beginning to explore. (showing of film clip.)

QUALITY & SPACE ACHIEVEMENT

NASA has scheduled a balanced, yet accelerated program for the step-by-step accumulation of space knowledge and associated technologies to meet this challenge and achieve real and enduring superiority in space. Since we must satisfy a difficult time schedule while efficiently using our national resources, we must ask industry to build the

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highest quality and reliability into small quantities of research type hardware. In fact, we require higher quality hardware than industry is presently producing. Furthermore, in addition to developing operational space systems, we ask industry to provide adequate confidence in each article by intensive and well defined quality programs.

REASONS FOR INTENSIVE QUALITY EFFORT

What are the practical reasons that greater quality effort is required for space flight? Perhaps thru an understanding of these reasons you and I can motivate ourselves and our associates. (See figure 1).

First, the tremendous complexity and the nature of space flight presently means very high unit costs. The cost per launch of a Saturn C-1 vehicle, for example, is estimated at 20-30 million dollars. Also, manned lunar exploration, scheduled to occur within this decade, necessarily involves costs exceeding, by many times, those presently experienced in simply placing man in an earth orbit.

Second, this very complexity and high cost means that we must schedule a lower density of launchings than involved in the development of any weapon system. Generally, only a few launches of any given configuration can be scheduled. Furthermore, space-operational use in the research sense, must be contemplated early in the development life of a launch vehicle or of a spacecraft. We cannot afford the luxury of large numbers of experimental flights to provide the traditional slow growth to reliability.

Third, the combination of high cost and relatively few launches of a given kind intensifies our need to avoid failures. We have experienced, and are still experiencing, avoidable failures. In view of our open policy on information concerning NASA space operations, I need not comment on the serious impact of flight failures upon our national prestige.

Fourth, manned space flight requires great care and attention to a myriad of details. In sum, the space systems involved in manned lunar exploration exceed in complexity and number of development tasks any project hitherto undertaken by this country. Manned space flight increases the number of the technical factors which must be balanced and resolved for mission success, while increasing our need for assurance of success.

Fifth, manned exploration of space requires super rocket engines for tremendously large, multi-stage launch vehicles of multimillion pounds thrust. High energy fuels are necessary in large quantities, making avoidance of blow-up at launch mandatory. For example, each two-stage Saturn C-1 requires almost 500 tons of fuel; the three stage advanced Saturn C-5 involves more than five times as much. Furthermore, these and other launch vehicles under development are powered in upper stages by liquid hydrogen, which operating at about 100 degrees lower cryogenic temperature than liquid oxygen. This fact poses very difficult fabrication and quality problems, while increasing the safety problem.

Sixth, operational readiness at specific times is needed for orbital operations and for lunar and interplanetary travel. Launch windows are restricted to very short periods and success is possible only when there is an optimum spatial relationship between the earth and the heavenly bodies to which we wish to travel. Rendezvous in orbit, a technique which offers great promise of accelerating the exploration of space, requires not only launch readiness at specific and limited times, but also great precision due to the high velocity of vehicles and spacecraft in orbit.

These then, are some of the compelling reasons that necessitate dedication to and iron discipline in quality effort by NASA installations and by industry.

QUALITY AND PROCUREMENT

Since about 90% of NASA's dollars are presently expended in contract effort, NASA's reliability and quality assurance policies are carefully integrated with each step of the procurement process. It is NASA's policy to place its quality and reliability requirements contractually and to provide for a clear understanding of its requirements at all times. These requirements contractually bind the prime to transmit pertinent quality requirements to each of his subcontractors; and the subs, in turn, to their suppliers.

Figure 2 shows the general sequence of reliability and quality events from preliminary idea to contract award. The establishment of requirements and the technical evaluation of bids receives the attention of NASA in-house experts in reliability and quality assurance. The Headquarters Office of Reliability & Quality Assurance reviews procurement plans for major space systems and participates in source evaluation proceedings. Emphasis is placed upon planned programs and upon the means of measuring conformance thereto.

Let us now consider the principal elements of the space system contractor's quality program and the associated major actions to be taken by him. (Figure 3). Note that the quality program includes requirements which extend beyond conventional quality control; also some elements are considered by many to have a reliability "handle." NASA's quality requirements start with the very concept of design and development; also NASA wishes to initiate all necessary and related quality actions without being denied full accomplishment because of a stated position: "We don't presently do that." Furthermore, NASA's reliability and quality requirements are complementary, depending upon recognition of requirements and planned actions, rather than on arbitrary definitions of words or particular company organizational divisions.

Figure 4 shows the principal elements of the space system contractor's reliability program. These requirements are detailed in the work statement for each major system procurement. The reliability program is then negotiated, giving each bidder the opportunity to describe his program and the methods to be used in demonstrating achievement of the specified reliability goals. NASA Headquarters is presently coordinating drafts of a reliability program requirements document, which will complement the recently issued NASA Quality Publications.

CONTRACT PROVISIONS

Basic, general quality requirements are invoked contractually by the NASA Quality Publications NPC 200-2 and 200-3, which are largely self-contained documents. Detailed quality specifications and standards are either cited in the procurement, or are required to be generated by the contractor as part of the research and development work.

Figure 5 shows the functional scope and kinds of space hardware to which each publication applies. The extent of NPC 200-2 requirements for the system contractor is more comprehensive than is NPC 200-3 for the supplier of materials, parts and components for end-use in space systems. Furthermore, NPC 200-3 was deliberately tailored to define minimum quality system requirements considering that small business shares our procurement dollar on both prime and subcontracts.

Both documents are intended to be applied, in whole or in part, to prime and to subcontracts. Having two documents not only provides for variations tailored to each procurement situation, but permits a separate focus on the small articles which arrive in the space system through subcontracts of the system prime, and through direct purchases by NASA installations. Many malfunctions and failures indicate there is not enough attention paid to quality by either the parts supplier or by the purchaser.

HIGHLIGHTS OF QUALITY PUBLICATIONS

Time does not permit review of all of the highlights of the NASA Quality Publications. They require extremely careful "understanding reading," not "speed reading". Their application involves engineering judgement coupled with knowledge of design and mission intent. I will point out only a few highlights.

Referring to figure 6, the system contractor is required to define his quality program in a written plan and to provide comprehensive documentation that will be reviewed by the contractor's management, by the inspection agency and by the NASA installation responsible for the quality of the research hardware procured. The corresponding requirement in NPC 200-3 for inspection systems also requires the supplier to prepare and maintain a written inspection plan. However, submission to the purchaser (who may be a NASA installation or a system prime) is required only when specified. Generally this is determined by the critical nature of the articles involved.

NPC 200-2 contains broad organizational requirements (figure 7) within which the contractor assigns quality program functions to competent individuals throughout the full scope of his operations, not only to inspectors and quality control personnel. In addition to assigning adequate responsibility and organizational freedom to effectively carry out the required quality functions, 200-2 requires that the ability of personnel to objectively assess, document and report true findings shall be maintained throughout the contract, undiminished by engineering changes, rework, or rescheduling.

Quality considerations for our complex space systems necessitates documentation of design control requirements and quality criteria thru all phases from development to end-use (see figure 8). Precision in research hardware must be matched by precision in documentation controls, including review by quality program personnel. The subject of qualified and preferred parts is presently treated only by individual contracts for certain programs. However, work is in progress to provide NASA-wide criteria, usage and mechanized data distribution for high reliability parts for space applications.

Broad requirements for qualification testing are shown on figure 9. These are supplemented by detailed requirements in the contract work statement. Generally, the system contractor is required to develop an integrated test plan to provide adequate confidence in the reliability of both experimental and flight articles. The qualification status list is a management tool for test decision-making and provides a ready index to test results for design reviews.

The elements of contractor's quality responsibilities for procured material shown on figure 10 are detailed in NPC 200-2. Less detailed but similar requirements are contained in NPC 200-3.

BREAK

While you take a stand-and-stretch break, you will hear the sounds recorded inside the blockhouse as the first Saturn nears the end of its perfect countdown and lifts off for a perfect flight on its very first trial. (Saturn Launch Tape).

HIGHLIGHTS CONTINUED

Some of the controls over contractor fabricated articles are shown on figures 11 and 12. Note that reference is made to documented "conformance" criteria, not "acceptance" criteria... which would mean government ownership. Measurement of conformance must occur at every step of the development, fabrication and shipment process, whereas acceptance occurs only once -- when flight articles are completely assembled and checked out. We are also encouraging the development of pride in the work an individual performs by requiring that inspection and fabrication operations be traceable to the individual responsible. Furthermore, personnel are required to qualify by training and certification. Some additional fabrication controls are shown on figure 13. These include traceability of identification on articles or records to relate inspection and test results with the particular articles forming a given space system. Age control involves recording variables data to ensure that articles provided will have adequate useful life after beginning a mission and despite prior tests and exercise. The control of cleanliness not only contributes directly to the quality of precision articles, but also has a beneficial psychological effect on personnel involved.

Process controls are highlighted in figure 14. Regarding certification of personnel, we certify operators at prime contractor's plants and are expecting the prime to be qualified to certify subcontractor's personnel. We are moving toward NASA training of contractor's personnel as certifiers, retaining the right to verify personnel proficiency. Process controls include documented procedures, including preparation and fabrication details. Process environments involve means of their maintenance and measurement.

Much importance is placed upon end-item or system tests, some highlights of 200-2 requirements being shown on figure 15. Altho we require a test plan for NASA approval, including parameters and tolerances, any unusual phenomena, difficulty, or questionable condition, should be reported. End-item tests are conducted at the plant and at test sites, such as static test towers for complete vehicle stages. The requirement to simulate end-use to the highest practical degree without damage means these are expensive tests. Accordingly, they must be carefully planned and controlled to be meaningful and permit valid conclusions, such as flight-worthiness. Here again, documentation is important to know the exact configuration under test as well to record test results. Both are subjects for mechanized data processing.

Figure 16 highlights corrective action, which includes preventive action on the basic causes. Significant is the requirement to take action on all malfunctions and troubles, discovered by any inspection or test operation at plant, test sites, launch sites and flight operations. Several systems contractors integrate reporting and procedures for materials review board and corrective action. In both cases, data reporting, analysis, and completed action are necessary. 200-2 contains detailed requirements for the elements shown on figure 16. Innovation and creativity in streamlining corrective action and providing time preventive action will pay large dividends in quality hardware.

CONCLUSION

Thru the contractual documents and procedures just described, NASA expects to obtain reliable flight hardware in fact, not on paper. And we expect this job to be done well, on time, and within cost budgets. This requires enthusiasm and understanding of the importance of quality by top management and by every member of the industry team.

In closing, I hope that my remarks on NASA's quality requirements have indeed helped your understanding and that from understanding will come effective, problem-solving action by all who are directly or indirectly participating in NASA's space programs. Such action will help provide timely development of operational space systems and adequate confidence of mission success and flight safety.

REASONS FOR INTENSIVE NASA QA EFFORT

- VERY HIGH UNIT COSTS
- LOW DENSITY OF LAUNCHINGS - SMALL QUANTITIES
- AVOIDANCE OF FLIGHT FAILURES
  - IMPACT ON NATIONAL PRESTIGE
- COMPLEXITY OF MANNED SPACE SYSTEMS
- CONSEQUENCES OF LAUNCH BLOWUPS
- FLIGHT READINESS AT SPECIFIC PERIODS
  - ORBITAL AND RENDEZVOUS OPERATIONS
  - LUNAR AND INTERPLANETARY TRAVEL

Figure 1

▶ FEASIBILITY STUDY	• CONSIDER RELIABILITY FACTORS
▶ REFINED CONCEPT	• ESTABLISH NASA RELIABILITY & QUALITY REQUIREMENTS
▶ PROCUREMENT	• EVALUATE BIDDER'S PAST & PROPOSED RELIABILITY & QUALITY PERFORMANCE

SPACE SYSTEM
CONTRACTOR'S RELIABILITY
& QUALITY PROGRAMS

Figure 2

SYSTEM CONTRACTOR'S QUALITY PROGRAM

▸ DESIGN & DEVELOPMENT	• PLAN QUALITY PROGRAM • ESTABLISH QUALITY CRITERIA
▸ PURCHASING	• CONTROL PURCHASE DOCUMENTS • INSPECT-SOURCE/RECEIPT
▸ FABRICATING	• PROCESS CONTROL & INSPECTION
• EXPERIMENTAL ITEMS • FLIGHT ITEMS	• QUALIFICATION & CONFORMANCE TESTING
▸ SYSTEM ASSEMBLY	• END-ITEM TESTING
▸ FLIGHT OPERATIONS	• DATA { * COLLECTION * ANALYSIS * FEEDBACK

Figure 3

SYSTEM CONTRACTOR'S RELIABILITY PROGRAM

(BASED ON NASA SPECIFIED GOALS)

- ORGANIZATION AND MANAGEMENT
- APPORTION GOALS TO SUBSYSTEMS AND COMPONENTS
- DESIGN FOR RELIABILITY
- PREDICT RELIABILITY - SYSTEMS ANALYSIS
- TEST: PERFORMANCE AND FAILURE RATES
- DEMONSTRATE SYSTEM RELIABILITY

Figure 4

CONTRACT QUALITY PROVISIONS

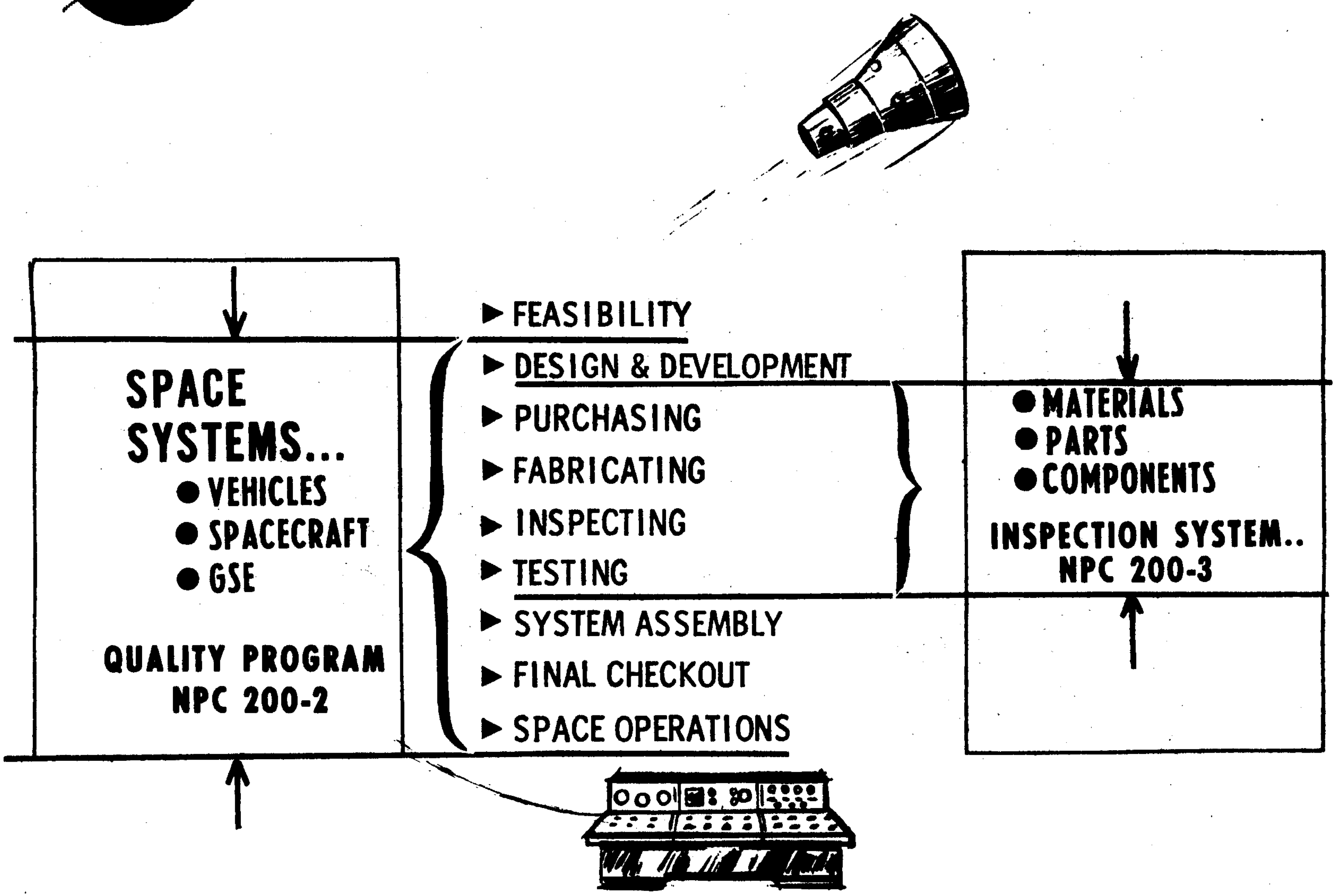

Figure 5

QUALITY PROGRAM PLAN (NPC 200-2)

- ▶ WRITTEN PLAN FOR NASA REVIEW
- ▶ FULL RANGE OF ACTIONS
- ▶ PRELIMINARY PLAN
  - FLOW CHART QUALITY OPERATIONS
  - REVISIONS AND ADDITIONS TO PRESENT OPERATIONS
  - TIME SCHEDULE-DOCUMENTS
  - ORGANIZATIONAL STRUCTURE-ALL PROGRAM FUNCTIONS
- ▶ DETAILED PLAN AS DEVELOPMENT PROCEEDS
  - INSPECTION AND TEST PLAN
  - END ITEM TEST PLAN-NASA APPROVAL
  - CHANGES AND ADDITIONS

Figure 6

ORGANIZATION (NPC 200-2)

- **SINGLE PATTERN NOT MANDATORY**
- **RESPONSIBILITY & ORGANIZATIONAL FREEDOM TO:**
  - RECOGNIZE & ASSESS QUALITY PROBLEMS
  - INITIATE, RECOMMEND AND/OR PROVIDE SOLUTIONS
- **EFFECTIVENESS OF FUNCTION & ABILITY OF PERSONNEL TO OBJECTIVELY ASSESS, DOCUMENT & REPORT TRUE FINDINGS:**
  - MAINTAINED THRUOUT CONTRACT
  - NOT DIMINISHED BY ENG. CHANGES, REWORK OR RESCHEDULING
- **DIRECTOR-UNIMPEDED ACCESS TO HIGHER MANAGEMENT**

Figure 7

DRAWINGS AND SPECIFICATIONS (NPC 200-2)

- **DOCUMENT FOR ALL PHASES-DEVELOPMENT THRU END-USE:**
  - DESIGN CONTROL REQUIREMENTS
  - QUALITY CRITERIA
- **REVIEW CONTRACTOR AND GOVERNMENT DRAWINGS, SPECS & TECHNICAL DOCUMENTS:**
  - ESTABLISH QUALITY & RELIABILITY CHARACTERISTICS
  - PROVIDE CRITERIA TO JUDGE CONFORMANCE
  - DOCUMENT DESIGN REVIEWS
  - MAXIMIZE USE OF QUALIFIED PARTS
  - PREPARE AND/OR APPLY PREFERRED PARTS LIST
    - ✓ELIMINATE PARTS KNOWN TO BE INADEQUATE
    - ✓AID IN PLANNING PART/COMPONENT TESTS

Figure 8

DESIGN & DEV CONTROLS (CONTINUED) (NPC 200-2)

▶ QUALIFICATION TEST REQUIREMENTS

- DEMONSTRATE DESIGN CAPABILITY
- LOCATE FAILURE MODES
- DETERMINE EFFECTS OF:
  - ✓ VARIED STRESS LEVELS
  - ✓ COMBINATIONS OF TOLERANCES AND DRIFTS
  - ✓ COMBINATIONS AND SEQUENCES OF ENVIRONMENTS AND OF STRESS LEVELS

▶ REQUALIFICATION TESTS

- OTHER TESTS ACCEPTED-NASA DISCRETION
- REPEAT AT INTERVALS SPECIFIED OR WHEN DATA INDICATES
- CORRECT BEFORE REQUALIFYING

▶ QUALIFICATION STATUS LIST

Figure 9

CONTROL OF PROCURED MATERIAL (NPC 200—2)

► CONTRACTOR RESPONSIBLE FOR ADEQUACY & QUALITY ALL PURCHASED MATERIALS, ARTICLES & SERVICES

- SELECT QUALIFIED SOURCES
- INCLUDE ALL DESIGN, RELIABILITY & QUALITY REQUIREMENTS IN SUBCONTRACTS & PURCHASE ORDERS
- EVALUATE ADEQUACY OF PROCURED ARTICLES
- PROVIDE EARLY INFO FEEDBACK & CORRECTION OF DEFICIENCIES
- PROVIDE TECHNICAL ASSISTANCE & TRAINING TO SUPPLIERS
  - ✓ AS NECESSARY TO ACHIEVE DESIRED RELIABILITY & QUALITY

Figure 10

CONTROL OF CONTRACTOR—FABRICATED ARTICLES

(NPC 200—2)

- ► MAINTAIN QC PROGRAM & DOCUMENTATION TO ENSURE CONTRACT, DWG & SPEC REQUIREMENTS ARE OBTAINED & MAINTAINED
  - PROVIDE MAXIMUM ASSURANCE QUALITY INHERENT IN DESIGN IS MAINTAINED
- ► PROVIDE DOCUMENTED CONFORMANCE CRITERIA
  - AVAILABLE IN ADVANCE & AT PLACE OF INSPECTION / TEST
- ► PLAN INSPECTIONS & TESTS DURING FABRICATION, PROCESSING & ASSEMBLY BASED ON :
  - ARTICLES
  - FABRICATION & PROCESSING OPERATIONS
  - MATERIAL INTEGRATION, ASSEMBLY & CHECKOUT
  - END-ITEM TEST PLAN

Figure 11

CONTROL OF CONTRACTOR—FABRICATED ARTICLES (CONT.)
(NPC 200—2)

- SELECT WORKMANSHIP INSPECTION STANDARDS
  - EARLY PHASES OF FABRICATION
  - REVIEW & REPLACE UPON DESIGN CHANGES
- PERFORM INSPECTIONS & TESTS—ALL FABRICATION OPERATIONS
  - OBSERVE, ANALYZE & RECORD NONCONFORMANCES
  - DEFECT PREVENTION & CORRECTIVE ACTION
  - OPERATIONS TRACEABLE TO INDIVIDUALS RESPONSIBLE
  - QUALIFY INSPECTION PERSONNEL PER TRAINING & CERTIFICATION REQUIREMENTS
- IN-PROCESS INSPECTION AT ESTABLISHED POINTS
  - AT OR BEFORE LAST POINT AT WHICH ACCEPTABILITY OF OPERATION OR QUALITY MAY BE VERIFIED
  - MINIMIZE DELAYS FROM DEFICIENCIES

Figure 12

FABRICATION CONTROLS (NPC 200—2)

- ENSURE INITIAL ACCURACY & REPEATABILITY DURING USE OF PRODUCTION TOOLING, JIGS & FIXTURES

- MATERIAL CONTROL
  - IDENTIFY & MAINTAIN ON ARTICLES OR RECORDS TRACEABLE TO ARTICLES
  - ENSURE ONLY CONFORMING MATERIALS / ARTICLES
  - REMOVE NON-CONFORMING MATERIALS / ARTICLES & CONTAMINATION BY RESIDUE
  - MARK AGE CONTROL & RECORD VARIABLES DATA
    - √ USE ARTICLES WITH ADEQUATE LIFE REMAINING
    - √ AFTER FABRICATION, STORAGE & OPERATION
    - √ RECORD REMAINING USEFUL LIFE

- CONTROL CLEANLINESS - PROPELLANTS, LUBRICANTS, CHEMICALS, & PRECISION ARTICLES, AS SPECIFIED NECESSARY TO MAINTAIN QUALITY
  - SPECIAL PROCEDURES DOCUMENTED
  - REVIEW & ENFORCE PROCEDURES, CLEAN OR WHITE ROOM REQUIREMENTS, INCLUDING CLOTHING

Figure 13

PROCESS CONTROLS (NPC 200-2)

- **DEFECT PREVENTION CONTROLS**
- **FABRICATION & INSPECTION PERSONNEL TRAINED & CERTIFIED**
- **PROCEDURES DOCUMENTED**
  - PREPARATION AND FABRICATION DETAILS
  - METHODS OF VERIFYING ADEQUACY
  - CONTROL PARAMETERS
- **PROCESS ENVIRONMENTS**
  - MAINTAINED AND MEASURED
- **CERTIFICATION OF MACHINES & PROCEDURES**
  - CONDITIONS FOR RECERTIFICATION
  - PERSONNEL PROFICIENCY SUBJECT TO VERIFICATION AND DISAPPROVAL BY NASA

Figure 14

END-ITEM TESTS & FINAL INSPECTION (NPC 200—2)

- TEST PLAN FOR NASA APPROVAL PRIOR TEST
  - TECHNICAL DESCRIPTION-SYSTEM, ASSEMBLIES & SUBASSEMBLIES
  - PARAMETERS TO BE INSPECTED & TESTED
  - NOMINAL & TOLERANCE VALUES
  - SEQUENCE OF TESTS
- TEST IN MANNER & CONDITIONS TO SIMULATE END-USE TO HIGHEST PRACTICAL DEGREE WITHOUT DAMAGE & PROVIDE VALID MEASURE OF QUALITY
  - DETAILED PROCEDURES FOR NASA APPROVAL
  - REPORT ANY UNUSUAL PHENOMENA, OCCURRENCES DIFFICULTY OR QUESTIONABLE CONDITION TO NASA/ DESIGNATED REPRESENTATIVE
  - SUBMIT DATA TO NASA

Figure 15

CORRECTIVE ACTION (NPC 200-2)

- ALL TROUBLES, MALFUNCTIONS, DEFICIENCIES & FAILURES
  - DISCOVERED BY CONTRACTORS, SUPPLIERS AND GOVERNMENT REPRESENTATIVES
  - DURING INSPECTION AND TEST AT PLANT, TEST SITES, LAUNCH SITES AND FLIGHT OPERATIONS
- DATA REPORTING, ANALYSIS & CORRECTIVE ACTION
  - COMPLETED ACTION ALL PHASES
- IMMEDIATE NOTIFICATION APPLICABLE ORGANIZATIONS
- ANALYSIS PERTINENENT DATA & ARTICLES
- PROMPT CORRECTIVE & PREVENTIVE ACTION
- REWORK ALL AFFECTED ARTICLES
- REVIEW ADEQUACY OF ACTION TAKEN
- CONTINUE REPORTS UNTIL ACTION IS ADEQUATE

Figure 16